SAFEGUARDING THE PROCESS OF ELECTRIC CAR BATTERY WITH BMS THEN CELL PAIRED SYSTEMS

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Abstract—Increasing Power demand and exhausting fossil fuels at a much higher rate than the rate of getting prepared leads to look towards the Renewable energy sources, but due to its On the other hand, commitment to reduce the carbon emissions and combating climate changes has been a driving force behind the rapid adoption of EV's. and its lifespan cannot be extended by reducing the amount of power consumed at a certain point, but with controlling the way the power is consuming. In addition to this, it uses acceptable techniques to get the cells of the battery as balanced by working to maintain equivalent state of charge of every cell, thus.

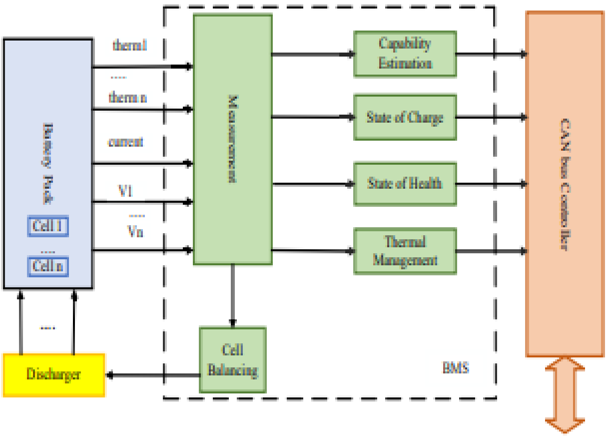
Keywords—EV (Electric Vehicle), BMS (Battery Management System), SoC (State of charge), SOH (State-ofhealth), EVSE (Electric vehicle supply equipment), PEU (Power electronics unit).

Introduction

Battery is a device that converts chemical energy contained within its active materials directly into electrical energy by means of an electrochemical oxidation-reduction (redox) reaction. Mainly used in portable, industrial, medical, traction/automotive, communication wide applications.

Transportation makes the biggest slice of green house gas emissions and direct impact on climate, driving an EV instead of fuel powered vehicle cuts the issues. Electric vehicles are the growing and complete future of transport. Therefore, it is necessary to develop more efficient EVs. Battery is the soul of any EV, a quality battery will give you better performance, range, and lifespan. Battery degradation due to physical properties (like internal chemical reactions) over the time cannot be modified, but due to operating parameters can be modified using a Battery management system (BMS), it comprises of various electrical and electronics circuits (like converter and inverter) led to produce maximum output and fail-free operation of the battery. The individual cells of the battery pack exhibit unequal discharge rates, capacities, temperature characteristics, and impedances. These variations may partially be mitigated by binning of cells, improving manufacturing at beginning of life, but over the time with the operation of the vehicle, these variations may increase and this can be controlled by the BMS system. prevent over charging and over discharging of the cells, thereby improves the overall pack efficiency and reliability and nullify the thermal runway conditions. For a battery, BMS system is necessary because of the following reasons:

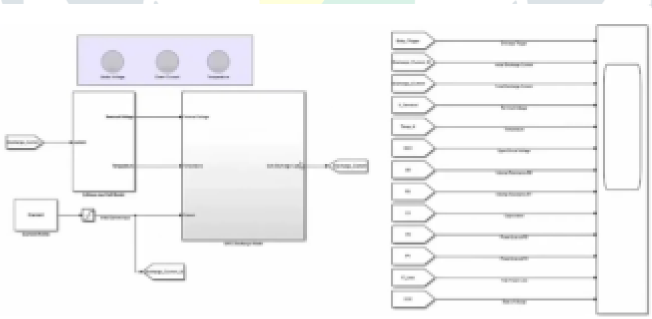
(i) To improving the operating/ working conditions. (ii) To improve charging/ discharging cycles, thereby enhance the capacity of battery. (iii) To improve the battery life by good balancing between the cells. (iv) To prevent short circuit, ground faults, and thermal runaway. (v) For electric power management by reducing the wastage of power in the form of heat and losses. (vi) To achieve extended service life, identify the better operating limits for specific applications.



Battery management system circuit overview

Battery state estimators estimates the following key concepts: State of Charge (SOC), cell voltages and currents, State of Health (SOH), internal temperature, power losses and joint state estimations.

Lithium-ion batteries powers the lives of millions of people every day from laptops, cell phones to Plug-in hybrid electric (PHEV) and electric vehicles, due to its high power density, light weight and ability to recharge. And much more efficient while charging and discharging compared to other storage systems, has quick recharge capability, longer cycle life, high temperatures handling capability. Thus, results in preferred choice for energy storage due to their efficiency and reliability. Most of the components of lithium-ion battery such as lithium, cobalt, manganese, and nickel, hold their value beyond the life of the battery, this provides an advantage of recycle those metals of about 95%, but the cost includes in recovery of the material become a challenge. And the drawbacks of these batteries are expensive in nature and has explosion chances. Many researches and developments are undergone to reduce their relative high cost, addresses safer concerns towards overheating and extends their working life. BMS system can control its explosion chances by controlling the overheating of cells by inducing cooling arrangement. Thereby we carried out the simulation on the lithium-ion battery as follows:



BMS modeling

Hence, the required values (discharge trigger, initial discharging current, final discharging current, terminal voltage, temperature, open circuit voltage, internal resistance R1, internal resistance R2, capacitance, power loss at R1, R2, total power loss, SOC) are measured and the obtained values are compared with the initial/basic/required values and the BMS system can undergone through process of controlling and stabilizing the battery operating conditions.

And the 3 indicator lamps are placed to indicate during the cases, when the obtained values are differed from its safe operating ranges that we assigned initially and thereby halt the charging or discharging operation for its safe operation and the 3 indicating parameters are under voltage, over current and over temperature.

SOC ESTIMATION:

In order to measure the battery's performance and its crucial states, it is important to estimate the state of charge (SOC) accurately, it is one of the crucial parameters of the lithiumion batteries. It describes how much charge is retained by the battery is fully charged or level of charge of an electric battery relative to its capacity. In order to obtain the better performance of the battery management system, it is important to estimate more accurate SOC. Not only for the representation of battery's remaining capacity but also prevents battery risks completely in advance. Thus, not only ensures safer operation of electric vehicles but also nullifies the risk to human life. Therefore, it is significant to carry research on SOC estimation.

SOC estimation is very important as correct values of SOC can determine the best operating strategies, errors in SOC estimation may lead to poor battery life and runtime, as well as potentially dangerous situations such as unexpected power loss in the system. Percentage of SOC represents the amount of energy that remains in the battery at a specific point of time. SOC is calculated based on proportional relationships between the electro motive force (EMF) of battery and its terminal voltage. As we know, by calculating the SOC, we address the information about the remaining capacity of the battery as a percentage value of the battery total capacity depending upon the level of charge. Based on this, BMS switches to charging or discharging under monitor and protects the battery from premature capacity loss and enhance its service life. SOC itself reflected as an accurate energy state indicator, calculation formula of it is as follows:

$$SOC = \frac{Q_C}{Q_0}$$

$$SOC = 1 - \frac{Q_T}{Q_0}$$

Where, Q0 = battery's initial electric quantity or rated charge at a certain temperature; QC = Battery's remaining electric quantity; QT = released energy from the battery. And final SOC is also calculated based on its initial parameter value and the various battery operating parameters, and it is given as,

INTERNAL TEMPERATURE:

Increased temperatures may cause thermal runway that results in failure of lithium-ion batteries. Thus, it is important to monitor and control the battery temperatures to prevent the failure of entire battery pack. Compared to lower temperatures, the chemical activity inside the battery is more at higher temperatures, results in reduced battery capacity at lower temperatures and increases with rising temperatures, and quick self-discharge and amplify corrosion, these mismatched conditions may affect the battery. Electric vehicle battery thermal monitoring using multiple thermostats may increases the size of the battery system, as many cells are packed closely to obtain higher power density, thereby the required number of thermostats are also increases in order to monitor individual cell. This tends to enhance the probability of malfunction of sensors, which prevents the robust thermal monitoring, and causes to raise the cost of maintenance. Extended exposure to high outdoor and internal temperatures leads to evaporation of fluids inside battery results in weakened charge. Lower and higher temperatures may lead to degradation of performance, reduced power capabilities, irreversible damages like lithium plating and thermal runaway, and this can be avoided by devising battery thermal characterization test under various operating conditions, as follows: Heat generated from the battery (Qgen), the amount that dissipated into surroundings (Qconv) and heat stored in the specimen (Qstor). This can be expressed by the following rectifying equation:

Where, V is the volume, ρ is density, h is the heat transfer coefficient, c is the heat capacity, A is surface area of battery, T and Ta is temperature of the specimen and ambient temperature, respectively. By this, the temperature generated rate can be concluded. The above equations give the base for any temperature characterization tests and based on the measured temperature values, activation of respective cooling system results in better operating conditions and optimized thermal runaway conditions.

POWER LOSS:

It was observed that over 12% to 36% losses occurred as one-way losses in the power transmission (from charging station) and conversion from the battery during the operation of an EV, so concerning and reducing loss factors is necessary to design and implement efficiently. Energy losses that occurred in a battery are due to many factors, among which are non-linear electrochemical reactions within the cells, un-desired management of the battery conditions, and internal resistances that results in the cell warming. While charging and discharging the EVs, power losses may occur in both the integrated vehicle system and building blocks that supplying the vehicle. This results in introduce the commercial operation for EVs and the grid services. Vehicles that have capability of such application called as grid-integrated vehicles, rather than charging only use case, this may use both charging and discharging cycles use cases for summing up to much more energy, therefore the predominant losses get reduced.

Most of the predominant losses are occurred in power electronic devices while AC to DC conversion. And this electronics efficiency is lowest at low SOC and low power transfer and affects more at discharging than charging. Based on these problems, two trouble shooting ideas are designed and proposed. First, analysing the optimal sizing of power supplying services that is charging stations. Second, developed an algorithm for dispatch of grid services to be operated at higher efficiencies, thus results in reduced losses of about 7% to 9.6% than using an algorithm of simple equal dispatch. And the power loss in a system can be simply represented by considering an experiment that consists of a set (of N number) of round-trips operated at standard SOC and current values. Let DC I be the current in the battery in Amperes and i t is the starting time, ci t be the duration of charging and di t duration of discharging, and the capacities of battery are calculated as follows:

$$C_{in} = \sum_{i=1}^{N} \int_{t_i}^{t_i + t_{ci}} I_{DC}(t)dt$$

$$C_{out} = \sum_{i=1}^{N} \int_{t_i + t_{ci}}^{t_i + t_{ci} + t_{di}} I_{DC}(t)dt$$

CELL BALANCING TECHNIQUES:

Cell balancing is also a major part of BMS system, cells in the battery pack have different parameters, impedances, voltage handling capabilities, various temperature characteristics, that tends to exhibit unique characteristics. This mismatched combining operation as a battery pack leads to inefficient operation and affects the reliability of the battery. Thus, cell balancing is an important factor to obtain the balanced cells, maximize the capacity thereby increased service life and reliable operation. This can be initially obtained by the manufacturing and binning of the cells. Although, over the period, parameters of the cells are continuously changes with working and this can be completely rectified by using various acceptable cell balancing techniques. Cell balancing helps to equalises the state of charge of all cells by transferring energy among the cells and keep the same level of charge across the battery pack. And this can be done by measuring the open circuit voltages, SOC after every charging cycle and comparing the state of all the cells. Integrated operation of BMS and comparison process leads to better results.

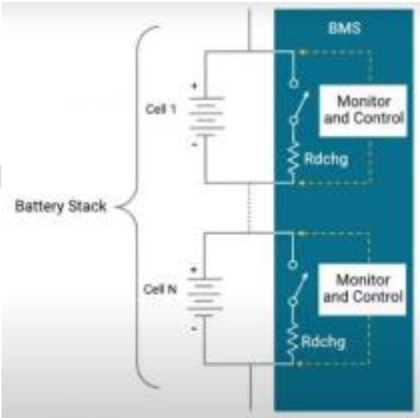
Usually, at the beginning of the life, battery pack may exhibit balanced and well-matched cells, but over the period it tends to degrades the matching nature of cells due to cyclic operations (charging and discharging), bad management of the battery pack, operating temperatures, general aging factor. This affects mostly the cells with weaker charge than cells with higher level of charge and tends to charge and discharge weak cells faster than the stronger ones, thus limits the battery run time and reduces reliability and efficient working. Batteries with similar chemical compounds, similar physical parameters like size and shape have different energy handling capabilities, internal resistances, and charging and discharging rates, aging, etc.

The performance of the battery pack may be limited by the weaker charge cells, and when they completely depleted, results in damage of entire pack by depleting the whole pack with the time. Thereby, monitoring and controlling the state and health of individual cells are necessary to operate the battery in a reliable way, to increase handling capacities, to increase efficiency and thereby extended service life. These measurements result in:

• Improves the health and state of charge of cells to their maximum level irrespective of the capacity. • Minimizes the SOC imbalances between the cells • Reduces the factor of aging affect

Cell balancing are of two types, based on the way of charge equalised and parameters among the cells, Passive and active. Each model has its own advantages and limitations based on the applications, and these are explained below in detail.

PASSIVE CELL BALANCING: In this Passive cell balancing method, equalises the charge of every cell as the level of weakest charge cell by drain off the excess energy by dissipating into heat using bleed resistors. During the charging cycles, small amount of energy of cells having greater SoC get drain off using small current, this process continues till all the cells get balanced, results in charging cells to their maximum SoC. This can be done by using a bleed resistor and a controlling switch, as shown in fig.



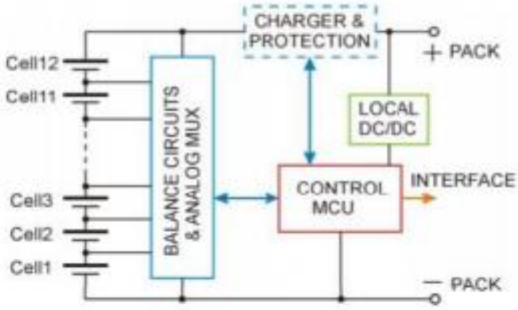
Passive cell balancer with bleed resistor

While operation, cells of the battery pack of same currents, weakest cell reaches to its maximum threshold voltage faster than other cells. When the voltage of any cell exceeds the safe operational area (SOA), results in partial damage of it. Since having easy design and building process without of much electronics, but this method is not much effective due to its dissipative nature of energy in the form of heat thus results in wastage. Using this, may the SOC of all the cells are balanced but does not result in improved run time of the battery. Advantages are relatively low-cost method of balancing and it corrects the mismatch for long time, the simulation modelling of it, is as shown in fig.

Using the voltage monitor integrated chips the voltage level of each cell gets monitored and measured values in Analog form are by means of the A/D converters. However, it is a dissipative method, it is more commercially implemented due to its easier control. Using the C-rates, the charge and the discharge amounts of the cells are governed.

ACTIVE CELL BALANCING:

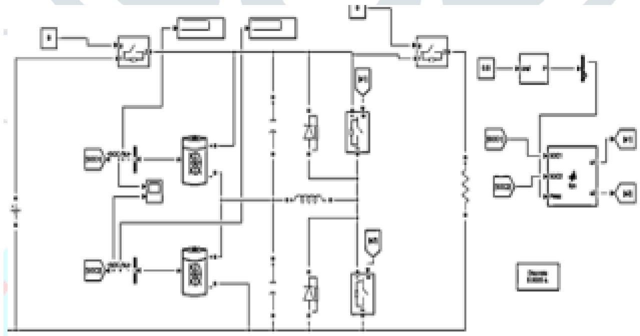
In this cell balancing method, the mismatched energy does not dissipate through a resistor as like passive cell balancing, but stored and transferred those excess amount to other weak state of charge cells, thereby obtained an equalised cells in the battery pack as shown in the below figure. The activity of storing and sharing the excess energy from high voltage cell to lowest voltage cells is done by using switched capacitors circuit. The additional charge of an overcharged cell is passed on to the cells which are relatively undercharged. Due to which the energy is theoretically not dissipated at all making it much more efficient than the Passive Cell Balancing technique. As no energy is dissipated, heat produced is less which enables higher power charge transfer which in fact makes the process of Cell Balancing much faster.



Active cell balancing circuit overview

Active cell balancing can be obtained in two different ways: by charge shuttling and by using energy converters. Charge shuttles are also known as flying capacitors, in this the capacitor is connected through SPDT switch, that triggers the charging and discharging of the capacitor from the cells of having greater SOC's, and when fully charged it fed that voltage to the lower SOC cells and thereby obtain the balancing. In Energy converters method, uses transformers and inductors to move excess energy among the cells of a battery pack. In parallel to the cells of the string the buckboost conversion method is used with a converter. During the charging period, all the cells can be balanced dynamically by this. Results in achieving balanced cells with greater efficiency and reduced losses in the circuit than other methods. In the same way,[8] uses directional dc-to-dc converters with a multi-winding transformer in order to summing up the charge equalization functionality during a trickle charging period to not only achieving the balancing of cells during the charging periods, but also in discharging periods. Though the circuit design is not complex, however required many electrical components that results in increased weight and overall cost of the system. Parallel operation is one that use buck-boost converters in parallel with a serially connected group of battery cells, reduces in component overhead while providing a stable DC voltage and nullifies charge imbalance.

Therefore, the problem of over-charging and overdischarging of the cells can be eliminated by this parallel configuration, in addition to this the cells that severely damaged or exhausted completely can be modified, isolated without of any turbulence to the system operation. The limitation of this method is, reduced efficiencies in overall energy conversion in parallel operation especially when the converter input voltage is much lower than its output voltage. This method has many advantages towards the easy design, and reduced cost. and the elimination of reducing energy efficiencies may be the possible choice for this research.



Modelling of active cell balancing method

Cycle life		>800 cycles
Operating temperature	charge	0 – 40 centigrade
	Discharge	-20 to 60 centigrade
Dimension	Thickness (mm)	8.4 (0.5 tolerance)
	Width(mm)	215 (2.0 tolerance)
	Length(mm)	220 (2.0 tolerance)
weight		860 (40 tolerance)

The simulation for battery management system is done by considering the model of KOKAM battery with a pack of cells of following specifications as shown above and the output is checked for various assigned limits of parameters for only the purpose of cross checking the operation of the BMS.

And the simulated outputs of a cell are as follows:

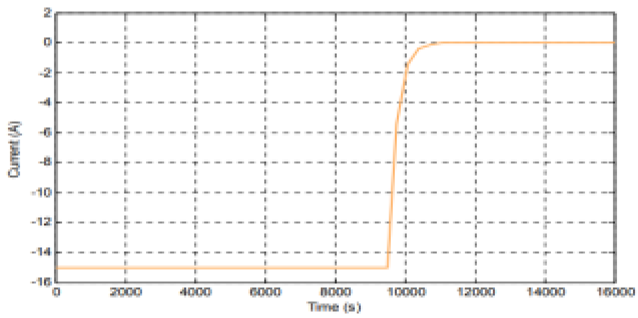
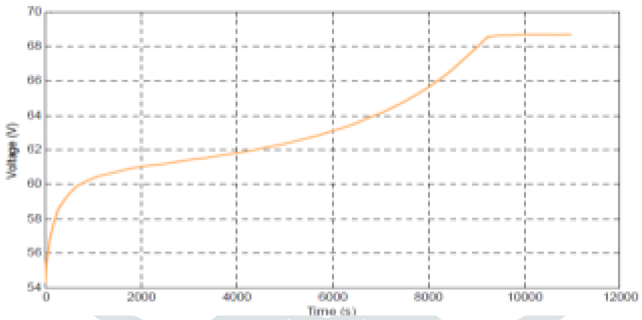
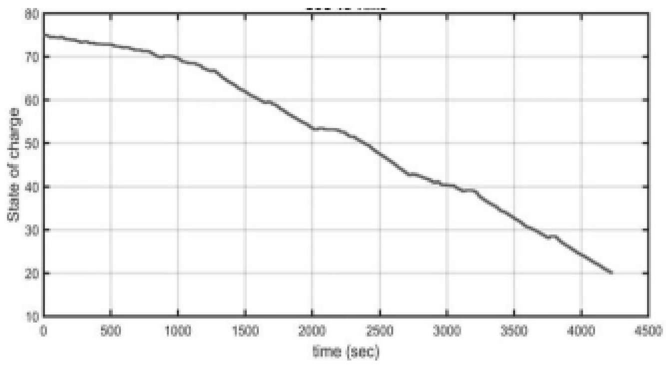


Figure 9: simulated charging current curve



Simulated charging current curve, simulated charging voltage curve

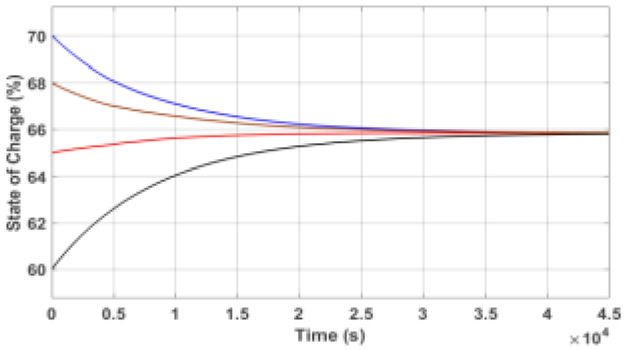


state of charge Vs Time

These are the modelling outputs of the battery parametric variations and now the simulation results of the cell balancing methods are obtained as follows.

The modelling output of passive cell balancing method is as shown below, that we can observe that the various cell voltages of various levels are tends to equalise the lowest cell voltage by dissipating all the excess energy by time and finally discharges all the excess amount of energy and gets equal amount of voltage in every cell.

And the active cell balancing model results are as shown below, that we can observe by the results, as the various cell voltages(SoC) are tends to equalises to a particular value by sharing the excess energy among the other cells and thus results in getting equalised voltages in all the cells.



Conclusion

Simulation is an important ally for not only the BMS system but for many models that solves the real time issues without of any hardware implementation and provides analysis and clear insights of a complex system, ensuring the optimization of the design and for easy prediction of the real changing processes. By this we can be able to easy verification, communicate and understand the key issues in it. And results in explore, and address the day-to-day challenges. Thereby simplifies the testing state, virtual prototype, physically really embedded situations for the hardware implementation.

In this paper, battery management system for a lithiumion battery pack modelling is done using MATLAB simulink, using various physical and the mathematical components as per the work building block requirement. different mathematical and physical components. And in that integrated collection of individual data like state of charge, operating voltages, currents, and temperatures are modelled combinedly to achieve the ultimate tasks like monitoring, controlling, and balancing. And the results of simulation modelling results in effective calculation of SOC, cell balancing required parameters, response of the battery and the safe and extended operation of the cells of the battery pack. Further work of extended BMS components and the effective improvement of states in balancing of cells may developed in the next step.

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